Low Rate Turbo-Hadamard Codes

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Abstract — **This paper presents a class of low rate turbo-Hadamard codes. Both simulation and analytical results are provided to demonstrate the advantages of the proposed codes. The proposed codes can achieve performance of BER=10^{-5} at $E_b/N_0\approx$-1.26 dB with an interleaver length of 65534 bits. It also has considerably lower decoding complexity compared with other low rate codes.**

Recently, it has been reported that a noticeable performance gain can be achieved by applying an iterative decoding mechanism to the convolutional code and Walsh sequence in the IS-95 system [1]. Since IS-95 is not originally designed for joint coding/spreading, the work in [1] implies that a properly designed low rate codes can further improve capacity and performance of CDMA systems.

This paper proposes a turbo-Hadamard coding scheme with very low decoding complexity. The structure of a component code in the proposed scheme is shown in Fig. 1. Information bits are arranged as an array $\boldsymbol{D}$. Let $\boldsymbol{d}_k$ be the k-th row of $\boldsymbol{D}$. The component code C is constructed as follows.

1. Let q'_k be the parity check of $\boldsymbol{d}_k$.
2. Use $\boldsymbol{q}'=\{q'_k\}$ to encode a rate-1/2 systematic recursive convolutional code $\hat{C}$, producing a redundant vector $\boldsymbol{q}=\{q_k\}$, i.e. $\{\boldsymbol{q}',\boldsymbol{q}\}$ forms a codeword of $\hat{C}$.
3. Use ($\boldsymbol{d}_k$, q_k) to encode a length-2^r Hadamard code (with r the length of $\boldsymbol{d}_k$), producing a parity sequence $\boldsymbol{p}_k$, where k=1, 2 ... K.

We thus have the component codeword in the form of {$\boldsymbol{D}$, $\boldsymbol{q}$, $\boldsymbol{P}$}, where $\boldsymbol{P}$={$\boldsymbol{p}_k$}. The intermediate vector $\boldsymbol{q}'$ does not appear in the final codeword.

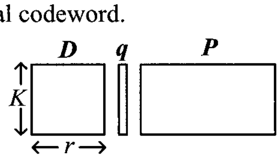

Fig. 1 Structure of the component code *C*.

The turbo-Hadamard codes are constructed by concatenating *M* component codes described above in parallel. Fig. 2 contains the performance comparison of the proposed codes and the super-orthogonal turbo codes [2]. It is seen that the proposed scheme can achieve performance of BER=10^{-5} at $E_b/N_0\approx$-1.26 dB (only 0.33dB away from the ultimate Shannon limit of −1.59dB) with an interleaver length of N=65534 bits.

The decoding complexity of the proposed codes is very low due to the following reasons:

Multiple information bits are encoded in each trellis section, which reduces the normalized decoding cost.

Very simple trellises (with only 2 or 4 states) are used. The decoding cost is mainly for the input/output stage, which can be efficiently handled by the fast Hadamard transform (FHT) and the *a posteriori* probability–fast Hadamard transform (APP-FHT) [3].

Table 1 below is a cost comparison between turbo-Hadamard code proposed in this paper and the super-orthogonal turbo code introduced in [2].

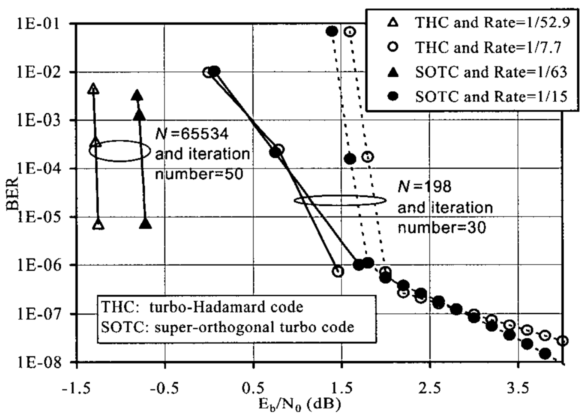

Fig. 2 Performance comparison between turbo-Hadamard codes and super-orthogonal turbo codes. The solid lines are for the simulated results and the dashed lines are for the union bounds.

Table 1 Complexity comparison of *N*=198 codes.
(Unit: operation numbers per information bit per iteration.)

	Rate 1/7.7 turbo-Hadamard code	Rate 1/15 super-orthogonal turbo code
Mult./div.	68	256
Exp./log.	26	32
Add.	147	216

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